REPORT OF COOPERATIVE RESEARCH ON INSECT CONTROL IN FARM STORED GRAIN

No. 6 Period--October 1 to December 31, 1942

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CORN STORAGE

Effect of Temperature on Insect Abundance in Corn Bins*

During November, all of the experimental bins in the commercial corn region were sampled.

The corn stored in the experimental series of bins has now been under observation for a year, and much of it has been in storage two years or longer. During the past year, quarterly observations have been made on the grade, insect infestation, and general condition of the grain. Little change in the commercial grade has been noted, with the exception of some deterioration of the surface grain in a few bins.

Temperature observations have shown that in normal, uninfested bins, the yearly temperature of the grain mass varies surprisingly little, and that changes in temperature take place very slowly, due to the insulating quality of the grain. In bins in the northern part of the area, the temperature in the center of the grain mass ranged from 27° F. in March to 68° F. in August. In the southern part of the region the range was from 38° to 82° F. The grain reached its maximum temperature in August, and the minimum temperatures were recorded in March. Thus during the past year there has been a fluctuation of from 27° to 39° F. in the temperature of corn stored in steel bins.

Insect infestation in the northern localities has been consistently lower than that in the southern portion. Low winter temperatures in the northern section reduced insect populations during the winter of 1941-42 to a very low level, and summer temperatures of the grain never rose high enough to permit rapid increase in population. In the southern part of the region, however, winter mortality was less and with higher summer temperatures, more rapid multiplication was possible. However, out of a total of 130 bins under observation, dangerous insect populations developed in only two bins in Henry County, Iowa, and five bins in Illinois.

Bin temperatures were generally lower in November, as compared with a similar period in 1941, and air temperatures during December have been considerably below normal, resulting in a much more rapid drop in the temperature of corn stored in steel bins than occurred during the winter of 1941-1942.

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* Reported by H. H. Walkden, J. M. Magner, and J. M. Wright in cooperation with the Bureau of Agricultural Chemistry and Engineering and State Entomology Departments of the several states in the Commercial Corn Area.

As regards the abundance of the various species of insects infesting stored corn, the sawtooth grain beetle (Oryzaephilus surinamensis) was taken in greatest numbers, with the flat grain beetle second in abundance. These two species constituted nearly three-fourths of the total number of insects found in the samples from the experimental bins in the commercial corn region. The various species, together with their comparative abundance are listed below:

Species	Percent of total
1. Sawtooth grain beetle (Oryzaephilus surinamensis)	41
2. Flat grain beetle (Laemophloeus minutus)	31
3. Rust-red flour beetle (Tribolium castaneum)	9
4. Foreign grain beetle (Ahasverus advena)	9
5. Cyaneus angustus	4
6. Hairy fungus beetle (Typhaea stercorea)	2
7. Dermestids	2
8. Indian meal moth (Plodia interpunctella)	1
All other species as listed below in order of abundance	1

9. Rice weevil (Sitophilus oryza), 10. Cadelle (Tenebroides mauritanicus), 11. Granary weevil (Sitophilus granarius), 12. Small-eyed flour beetle (Palorus ratzeburgi), 13. Spider beetles, species undetermined, 14. Yellow meal worm (Tenebrio molitor) 15. Black fungus beetle (Alphitobius piceus), 16. Black flour beetle (Tribolium maidens) and 17. Two-banded fungus beetle (Alphitobius bifasciatus).

Special Studies on Insect Infestations in Corn in Illinois*

Routine sampling of experimental bins in seven counties of northern Illinois showed that the rust-red flour beetle, Tribolium castaneum, and the sawtooth grain beetle, Oryzaephilus surinamensis, are the two most abundant species. These are followed by the flat grain beetle, Laemophloeus minutus, and the foreign grain beetle, Ahasverus advena. Small numbers of dermestids, anthocorids, and Cynaeus angustus were encountered. The latter was recorded in any abundance only from Whiteside County. Only occasional hymenopterous parasites were encountered.

Routine temperature readings were taken in all experimental bins once during the quarter. Temperatures were normal with the exception of bins 105, 106, and 107 at Thomasboro, Champaign County, Illinois, (See Table 1). High temperatures in these bins, apparently caused by large insect populations, necessitated shipping the corn. Temperatures in bins 210 at Rock Falls, Whiteside County, and B6 at Biggsville, Henderson County, Illinois, were also high, Corn in bin 210 at Rock Falls was turned prior to May, 1941 while the corn in bin B6 at Biggsville has never been turned.

Moisture percentages in the corn in experimental bins were also normal with the exception of bins 105, 106, and 107 at Thomasboro (See Table 2), bin 210 at Rock Falls, and a few others which had rotten corn on top. Moisture ranged from 10 to 15 percent in most bins with but few going higher.

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* Reported by J. M. Wright in cooperation with Dr. M. D. Farrar, Research Entomologist, Illinois Agri. Expt. Station.

When it was found that temperatures and moisture contents of corn in bins 105, 106, and 107 at Thomasboro had risen to exceedingly high points (see Tables 1 and 2), it was suggested by Dr. M. D. Farrar that the grain be shipped. Accordingly, on December 7, 8, and 9, 1942, the bins were emptied and the grain was shipped. In an effort to discover the cause of the grain's heating, insect samples were taken at intervals of three feet in the center, four feet and eight feet north and south of center as the corn was removed. At the half-way point and the bottoms of the bins samples were taken at center, four feet, six feet, and eight feet north and south of center. Samples were taken with a scoop shovel, and each sample consisted of the screenings from approximately one peck of corn. Insect populations are shown in figures 1, 2, and 3.

The above mentioned bins were situated on a low spot of ground which at times had been flooded, wetting the corn in the bottoms of the bins. It was found that there was a layer of rotten corn (moisture content 28.70 plus percent) two to four inches deep on the bin floors, above which the corn was dry. These bins had also developed leaks at the bolts near the tops of the side walls. As a result large masses of spoiled corn six to eight inches deep and one to four feet high were hanging on the sidewalls. This apparently was the cause of the bins' heating. The corn had become wet and insect populations had built up to such a degree as to cause heating in the corn.

Table 1: -- Temperature readings in bins 105, 106, and 107 at Thomasboro, Champaign County, Illinois, November 9, 1942.

	Temperature in degrees Fahrenheit				
Bin No.	Floor	3 feet*	6 feet	9 feet	12 feet
105	94	89	90	86	71
106	105	103	96	90	69
107	80	82	82	83	74

* Distance above floor.

Table 2: -- Vertical moisture records of bins 105, 106, and 107 at Thomasboro, Champaign County, Illinois, November 8, 1942.

	Vertical moisture in percent					
Bin No.	1*	2	3	5	7	9
105	16.31	16.96	14.41	12.56	12.60	11.79
106	16.81	17.27	15.52	12.92	12.45	11.99
107	22.40	20.02	13.64	12.97	12.31	12.17

* Cell numbers of five-foot grain probe starting with number one at handle and reading down.

2740

S.	0			50			1000			100		1
Fl.	1000			500			500			500		10000
R.	4			75			3000			1000		0
FG.	0			3000			200			50		0
L.	* 34			* -			* 0			* 5		0 *
		12 Ft.										
	0			2			0			500		0
	21			5			0			200		2
	0			0			150			1000		2
	0			1			4			100		0
	* 0			* 0			* 0			* 2		0 *
		9 Ft.										
	0	0		4			300			0	0	1
	16	16		225			200			200	26	3
	0	0		9			500			15	4	0
	0	0		4			10			60	5	0
	* 1	* 1		* 0			* 1			* 2	* 3	0 *
		6 Ft.										
	0			0			0			0		1
	33			25			3			76		30
	1			15			300			27		1
	2			41			500			71		2
	* 2			* 60			* 0			* 3		5 *
		3 Ft.										
	0	0		0			0			0	0	0
	24	1000		5			200			500	500	5
	6	0		0			80			1	21	1
	8	200		1			300			100	500	3
	* 2	* 2		* 1			* 2			* 4	* 0	1 *
		Floor										

Figure 1: -- Insect population in Bin 105 as indicated by insects screened from $\frac{1}{4}$ bushel samples of corn taken from various points in bin. Thomasboro, Ill. Dec. 7, 1942.

S. = Sawtooth grain beetle
Fl. = Flat grain beetle
R. = Rust-red flour beetle
FG. = Foreign grain beetle
L. = Larvae

* indicates sampling position.

2740

S.	0		150	100	50		50
Fl.	1000		300	500	800		500
R.	0		700	5000	1700		3
FG.	100		200	0	2		7
L.	* 5		* 0	* 0	* 5		14 *
12 Ft.							
	1		4	500	3		1
	3		6	100	1		5
	0		3	5000	5		0
	1		7	0	0		1
	* 2		* 1	* 0	* 0		1 *
9 Ft.							
	0	0	42	500	12	5	0
	13	60	3	100	7	75	7
	0	2	38	10000	5	10	0
	0	0	18	100	5	200	0
	* 2	* 2	* 10	* 0	* 4	* 3	0 *
6 Ft.							
	0		0	0	0		0
	38		100	200	50		12
	5		43	1000	125		1
	1		600	500	50		0
	* 3		* 0	* 0	* 25		0 *
3 Ft.							
	0	0	0	0	0	5	0
	26	500	200	100	1000	100	16
	3	0	4	2000	400	30	0
	6	5000	22	100	300	1000	0
	* 7	* 0	* 3	* 0	* 100	* 0	0 *
Floor							

Figure 2: -- Insect population in Bin 106 as indicated by insects screened from $\frac{1}{4}$ bushel samples of corn taken from various points in bin. Thomasboro, Illinois, Dec. 8, 1942.

S. = Sawtooth grain beetle
Fl. = Flat grain beetle
R. = Rust-red flour beetle
FG. = Foreign grain beetle
L. = Larvae

* indicates sampling position.

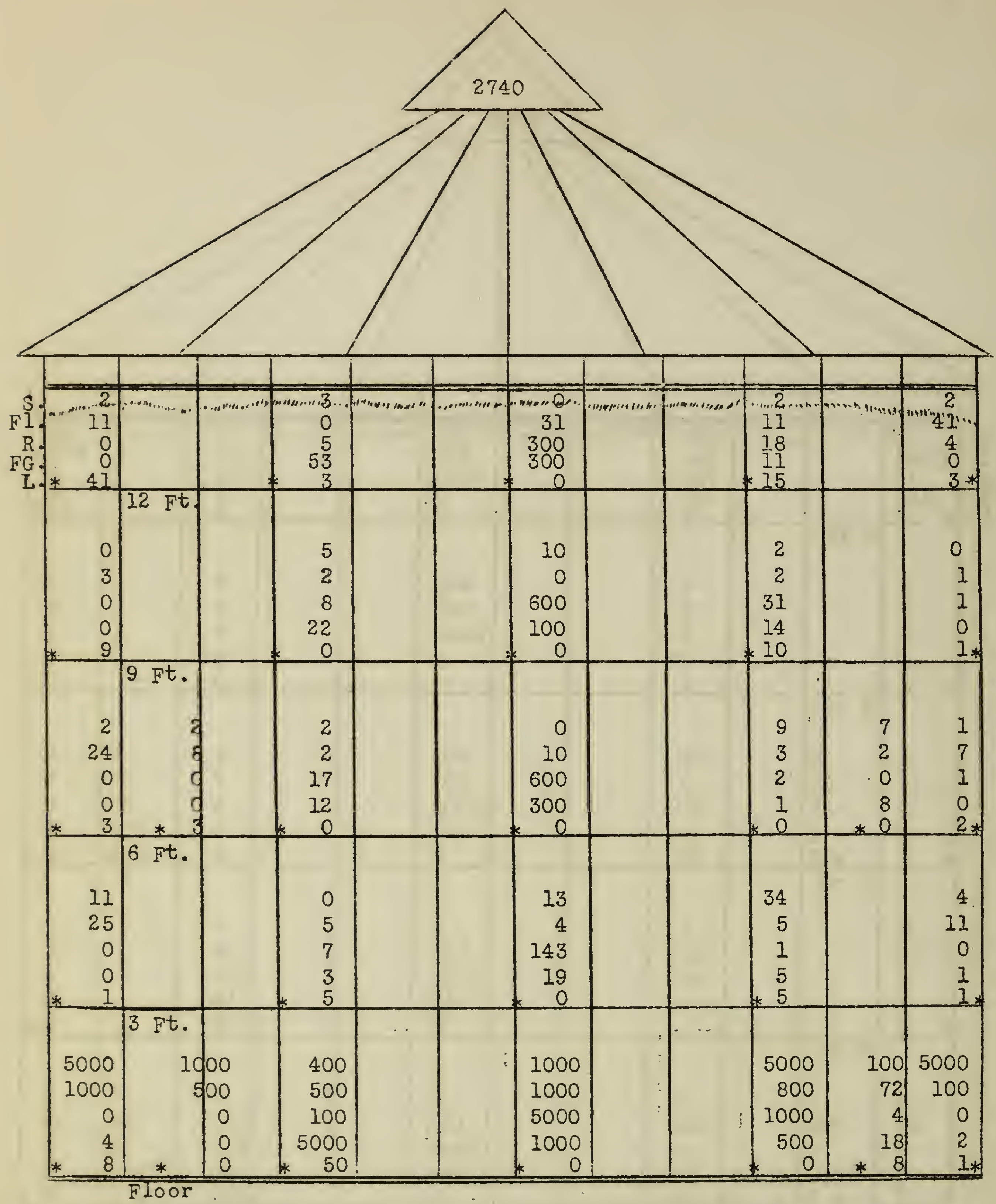

Figure 3: -- Insect population in Bin 107 as indicated by insects screened from ¼ bushel samples of corn taken from various points in bin. Thomasboro, Illinois, Dec. 9, 1942.

S. = Sawtooth grain beetle
Fl. = Flat grain beetle
R. = Rust-red flour beetle
FG. = Foreign grain beetle
L. = Larvae

* indicates sampling position.

Fumigation of Wheat in Illinois*

During the quarter twenty-three steel bins and eight plywood bins of wheat were fumigated experimentally. Four treatments were used: Br-10 at rates of 2, $2\frac{1}{2}$, and 3 gallons per 1000 bushels of wheat, and Dowfume 75 at the rate of 5 gallons per 1000 bushels of wheat. Results are shown in tables 3 and 4.

In eleven of the steel bins fumigated with 2 gallons of Br-10 per 1000 bushels of wheat, the test probes were removed after having been in the grain for only 7 days, while in the remaining five bins treated likewise the probes were allowed to remain 14 days. An appreciable number of insects were still alive after 7 days, but a perfect kill was obtained in 14 days. Satisfactory kills were obtained from all treatments except where test probes were removed after one week.

In one plywood bin, prior to fumigation with Dowfume 75, temperatures were high in the top half of the bin, 101° and 108° F. at the six-foot and nine-foot levels, respectively. Fourteen days after fumigation there was a perfect kill in the top cells of the test probe, but below that point few, if any, insects were killed. Apparently the hot wheat retained the fumigant and prevented its circulation to the bottom half of the bin, with the result that the insect population in the bottom half of the bin closely resembled that of the control bin.

In two steel bins fumigated with 2 gallons of Br-10 per 1000 bushels of wheat, test probes were inserted 4 days after fumigation and allowed to remain for 9 days. Results were an 88 percent kill in one bin and 42 percent kill in the other, demonstrating the variability of penetration of the fumigant in different bins. A perfect kill was obtained in both bins where the test probes were inserted at the time of fumigation but apparently the fumigant in one bin circulated rapidly and disappeared, while that in the other bin was partially retained.

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* All fumigation experiments were carried on by Dr. M. D. Farrar, Research Entomologist, Illinois State Natural History Survey.

Table 3 : -- Fumigation experiments in steel bins, Illinois.

Number of bins	Fumigant	Amount (gals.)	Floor	3 feet	6 feet	9 feet	Days test probe in grain	Position of probe	Rust-red flour beetle	Rice weevil	Granary weevil	Lesser grain borer	Sawtooth grain beetle	Flat grain beetle	Larvae	Hymenopterous parasites
	Material applied per 1000 bushels wheat		Average temperatures of grain (°F.) at 3-foot intervals from floor						Average number of live insects in seven check cells after fumigation compared with unfumigated control cells -- second figure*							
11	Br-10	2	68	75	81	67	7	D	1.9-155.2	0 -169.2	0-0	1.2-305.7	0-0	2.6-705.8	1.1-23.3	0-0
								S	15.9- 68.8	12.3-115.5	0-0	35.5-341.8	0-0	69.8-520.3	10.3-45.5	.1-0
5	Br-10	2	67	74	78	70	14	D	0 -155.2	0 -169.2	0-0	0 -305.7	0-0	0 -705.8	0 -23.3	0-0
								S	0 - 68.8	0 -115.5	0-0	0 -341.8	0-0	0 -520.3	0 -45.5	0-0
7	Br-10	$2\frac{1}{2}$	69	74	74	72	14	D	0 - 79.3	0 -204.2	0-0	0 -586.8	0-2.3	0 -536.7	0 -43.2	0-3.5
								S	0 - 71.2	0 -163.3	0-0	0 -694.3	0-0	0 -617.2	0 -52.5	0-1.2

* Only 6 cells of control probe counted, averages weighted.

Table 4 : -- Fumigation experiments in plywood bins, Illinois.

Number of bins	Material applied per 1000 bushels wheat: Fumigant	Material applied per 1000 bushels wheat: Amount (gals.)	Average temperatures of grain (°F.) at 3-foot intervals from floor: Floor	3 feet	6 feet	9 feet	Days test probe in grain	Position of probe	Rust red flour beetle	Rice weevil	Granary weevil	Lesser grain borer	Sawtooth grain beetle	Flat grain beetle	Larvae	Hymenopterous parasites
									Average number of live insects in seven check cells after fumigation compared with unfumigated control cells -- second figure*							
4	Br-10	$2\frac{1}{2}$	59	75	92	97	14	D	4.7 - 79.3	2.0-204.2	0-0	18.3-586.8	0-2.3	20.0-536.7	1.3-43.2	0-3.5
								S	0 - 71.2	0 -163.3	0-0	0 -694.3	0-0	0 -617.2	0 -52.5	0-1.2
2	Br-10	3	67	85	98	93	14	D	0 - 79.3	0 -204.2	0-0	0 -586.8	0-2.3	0 -536.7	0 -43.2	0-3.5
								S	0 - 71.2	0 -163.3	0-0	0 -694.3	0-0	0 -617.2	0 -52.5	0-1.2
1**	Dow-fume 75	5	60	74	90	103	14	D	0 - 79.3	0 -204.2	0-0	0 -586.8	0-2.3	0 -536.7	0 -43.2	0-3.5

* Only 6 cells of control probe counted, averages weighted.

** One of two bins fumigated with Dowfume 75, see page 7 of this report. Diagonal probe only taken in this bin.

Insect Problems of Soybean Storage*

The harvesting of the largest soybean crop on record, together with limited processing facilities has necessitated storage of large quantities of soybeans in steel and wooden bins owned by the Commidity Credit Corporation. It is expected that a portion of these beans will remain in this type of storage for a year and perhaps for a longer period.

In order to obtain information on the insect problems which may affect the safe storage of soybeans over a long period of time, a cooperative project has been set up with the Agricultural Adjustment Administration, the Bureau of Agricultural Chemistry and Engineering, the Illinois Agricultural Experiment Station, and the Iowa Agricultural Experiment Station.

This project will follow a line of investigation similar to that for corn, and will include a study of the changes in quality, temperature, and insect population in soybeans stored in steel and wooden bins.

Bins are under observation in three counties in Iowa--Henry, Cerro Gordo, and Osceola.

In Illinois, the selection of bins is now in progress, and observation sites will be set up in the following counties: Champaign, Iroquois, McLean, LaSalle, Whiteside, McDonough, and two others in the southern part of the state. It is planned to make periodic inspections at intervals of approximately six weeks, taking temperatures and sampling. The samples will be examined for insect infestation, and the moisture content, germination, fat acidity, and commercial grade will be determined.

A study is also to be made of the effectiveness of the common grain fumigants in order to establish minimum lethal dosages for the various types of bins. Tests of new fumigants will be made as they become available.

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* Reported by H. H. Walkden, J. M. Wright, in cooperation with the Bureau of Agricultural Chemistry and Engineering, the Illinois Agricultural Experiment Station, and the Iowa Agricultural Experiment Station.

WHEAT STORAGE

Conditions of Wheat in Steel Bins at Experimental Storage Sites*

During October and November, the regular quarterly samples were taken from the bins at both Jamestown, North Dakota, and Hutchinson, Kansas. From 1 to 5 quarts of wheat from each bin were examined for insect infestation. The insect populations at Jamestown continue at a very low point, only two living insects having been found in the entire lot of samples, representing an infestation of less than one percent of the bins.

At Hutchinson, 79 percent of the bins were found to be infested with insects, 58 percent grading weevily. As noted in the previous report, a tremendous increase in populations occurred during July and August.

A comparison of the infestation at the two storage sites since October, 1941, is given in table 5. The table brings out the great difference in insect populations at the two storage sites. At Jamestown, no dangerous insect populations have developed during 18 months of storage, while at Hutchinson, insect infestation has been a serious problem throughout the entire storage period. The rapidity with which dangerous insect populations developed at Hutchinson is well illustrated in the table: early in July, 1942, none of the bins graded weevily, but three months later 58 percent of the bins were assigned the weevily grade.

* Reported by H. H. Walkden, R. B. Schwitzgebel in cooperation with the Bureau of Agricultural Chemistry and Engineering.

Table 5:--Comparison of insect infestation in wheat stored in steel bins at Jamestown, North Dakota, and at Hutchinson, Kansas, October, 1941 to November, 1942.

	Oct.-Nov., 1941		Jan.-Feb., 1942		Apr.-May, 1942		July-Aug., 1942		Oct.-Nov., 1942	
	Bins infested (%)	Bushels infested (No.)	Bins infested (%)	Bushels infested (No.)	Bins infested (%)	Bushels infested (No.)	Bins infested (%)	Bushels infested (No.)	Bins infested (%)	Bushels infested (No.)
				Jamestown, North Dakota						
"Weevily" bins	1	2,700	1	2,700	0	0	0	0	0	0
Infested, but not weevily	18	40,000	6	16,000	4	13,500	5.6	16,500	0.7	2,700
Total infested	19	42,700	7	18,700	4	13,500	5.6	16,500	0.7	2,700
Total number of bins sampled	139		133		139		142		146	
				Hutchinson, Kansas						
"Weevily" bins	9	31,000	16	41,000	1.5	5,300	0	0	58	170,000
Infested, but not weevily	31	74,000	53	137,000	58.5	159,000	43	130,000	21	38,000
Total infested	40	105,000	69	178,000	60	164,300	43	130,000	79	208,000
Total number of bins sampled	144		135		135		124		133	

The wheat at Hutchinson is stored in bins of varying capacities, the bulk of it, however, being in 1000-bushel or 2740-bushel bins. In table 6 is given a comparison of the different capacity bins, showing the percentage of infested bins which required fumigation as a result of insect activity during the past season. It may be noted that 55 percent of the 1000-bushel bins required two fumigations to keep the insect infestation under control, whereas, in bins of 2740-bushel capacity only 4 percent required two fumigations, and in these the infestation developed as a result of cleaning and turning operations in a nearby bin. It is also significant that approximately one-third of the 2740-bushel bins required no treatment. The lower average temperature in 2740-bushel bins no doubt inhibits the rapid increase in insect population.

In all but two cases where heating occurred in 2740-bushel bins, heavy infestations of the lesser grain borer were found to be responsible. The two exceptions were cases in which infestation by the flat grain beetle caused abnormal rise in the temperature of the grain.

In 1000-bushel bins which were heating, the insect population consisted of more than one species; hence, the heating could not be attributed to any one species.

Table 6.--Comparison of the degree of insect infestation in 1000- and 2740-bushel bins, Hutchinson, Kans. July to December, 1942.

Capacity (bu.)	Number of bins	Percent needing no fumigation	Percent needing one fumigation	Percent needing two fumigations	Total percent needing fumigations
1000	44	2	43	55	98
2740	53	32	64	4	68

Nine species of stored grain insects were found in the quarterly samples at Hutchinson, and only one species at Jamestown. These species and their comparative abundance as shown by the several quarterly samplings are given in table 7. It will be seen that the rice weevil, lesser grain borer, flat grain beetle, sawtooth grain beetle, and rust-red flour beetle are the most abundant of the various species found in the grain stored at Hutchinson. The table also brings out clearly the very great difference in the insect populations at Jamestown and at Hutchinson.

Table 7:--Comparative abundance of the various species of insects found in stored wheat, Hutchinson, Kans., and Jamestown, North Dakota, October, 1941 to November, 1942.

Species	Hutchinson, Kansas 1941	Hutchinson, Kansas 1942				Jamestown, N. Dakota 1941	Jamestown, N. Dakota 1942			
	Oct.	Jan.	Apr.	July	Oct.	Nov.	Feb.	May	Aug.	Nov.
Rice weevil (*Sitophilus oryza* L.)	101	46	46	22	33	1	0	0	0	0
Granary weevil (*Sitophilus granarius* L.)	0	3	1	2	0	8	0	0	0	0
Lesser grain borer (*Rhizopertha dominica* F.)	530	81	3	5	267	0	0	0	0	0
Flat grain beetle (*Laemophloeus minutus* Oliv.)	112	403	172	39	720	31	23	3	5	0
Rust-red flour beetle (*Tribolium castaneum* Hbst.)	20	670	28	20	59	1	0	0	0	2
Sawtooth grain beetle (*Oryzaephilus surinamensis* L.)	4	3	1	6	90	0	0	1	1	0
Foreign grain beetle (*Ahasverus advena* Waltl.)	4	2	0	2	1	2	0	0	0	0
Long-headed flour beetle (*Latheticus oryzae* Waterh.)	0	3	0	0	1	0	0	0	0	0
Cadelle (*Tenebroides mauritanicus* L.)	3	5	1	0	0	0	0	0	0	0
Hairy fungus beetle (*Typhaea stercorea* L.)	0	0	0	0	1	0	0	0	0	0
Indian meal moth (*Plodia interpunctella* Hbn.)	0	0	0	0	1	0	0	0	0	0
Coninomus sp.	0	0	0	0	0	1	0	0	0	0
Dermestid larvae	1	0	0	0	0	0	0	0	0	0
Undetermined larvae	12	6	1	2	0	0	0	3	8	0
Totals	787	1222	253	98	1173	44	23	7	14	2

As outlined in earlier reports, several groups of bins were designated at both Jamestown and Hutchinson to receive different treatments in order to establish the most practical and economical storage practices for wheat stored in steel bins; those have been termed the "management investigation bins".

At Jamestown, consistently low insect infestations have prevailed throughout the storage period, and consequently, there has been no differentiation between the different management practices.

At Hutchinson, however, differences are now discernible. Table 8 gives the October, 1942, condition of the bins with reference to insect infestation. It will be seen (1) that only the series receiving two annual fumigations had no weevily bins in October, as a result of regular fumigations, and (2) that practically all of the bins under the other management practices became weevily and will require treatment to put them in good condition to go through the winter.

In this connection it should be borne in mind that inasmuch as the storage at Hutchinson is experimental, much of the grain in the "treatment when necessary" series has been carried as far as possible before applying treatment. Many of these bins have already been treated as called for in the management procedure. Thus, it appears that fumigation at least once and probably twice annually will be required at Hutchinson to prevent serious insect damage.

Table 8:--Comparison of insect infestation of bins in the management investigation series, Hutchinson, Kansas, October, 1942.

Treatment	Number of bins	Number of weevily bins	Number infested but not weevily
1. No treatment, no initial fumigation	2	1	1
2. No treatment, after initial fumigation	12	8	4
3. Oil spray on surface, June and September	9	6	2
4. Fumigation, June and September	9	0	3
5. Turning in January	10	9	1
6. Fumigation when necessary	19	19	0
7. Turning and cleaning when necessary	7	7	0
8. Turning, cleaning, and fumigation when necessary	5	4	1

Fall Distribution of Insect Populations in Wheat Stored in Steel Bins

During October and November, insect traverses were made in a series of bins at Hutchinson to determine the fall pattern of insect distribution in the grain. Twelve 1000-bushel bins and sixteen 2740-bushel bins were studied.

In 1000-bushel bins insects were found to be generally distributed throughout the grain, with greater numbers of them in the south and west quadrants of the bins. Such a distribution indicates that the insects inhabit the warmer portions of the grain. This pattern is similar to that found during the summer months. At the time these observations were made grain temperatures had fallen slightly from the summer peak.

In 2740-bushel bins, the greater portion of the population was found to be concentrated near the south wall of the bins from a point about four feet above the floor to about two feet below the surface. Laterally this concentration extended 4 to 6 feet along the wall. But few insects were found in other portions of the grain. The lesser grain borer and the flat grain beetle predominated, and it was noted that much fine material was present in the more heavily infested parts of the bins, as a result of the feeding activity of the insects.

Survey of Insect Infestation in Wheat Stored in Commodity Credit Corporation Bins in Kansas

During October a limited survey of the condition of wheat in Commodity Credit bins was made in four counties in Kansas. As a result of this survey it appears that a high percentage of such bins contain rather heavy infestations, some of which have reached the dangerous stage. The results of the survey are summarized in table 9.

Table 9 : -- Survey of insect conditions in wheat stored in Commodity Credit bins in Kansas, October, 1942.

Location	Bin identification: No.	Kind	Size	Moisture	Temperature: High	Ave.	Number live insects: F	RW	S	L	FG	GW	RF	Cd	Date
	205			11.1			3								
Bloom,	206			10.8			4							1	
Ford	207			11.3			13	11							10/12/42
Co.	208			11.2								1			
	227	Steel	2000	11.2	78	77	1								
	202	Steel	2000	11.1	75	74	5								
Colby,	203			11.0								1			
Thomas	206			10.6			11		1			1			
Co.	207			10.7			20					9			
	208			10.8			8					3			
	301			12.1			13		3			2	3		
Lincoln,	302			12.3			9		1						
Lincoln	303	Steel	2000	11.3	71	70	11						1		10/14/42
Co.	305			12.6			10	2	3				1		
	306			12.8			14		5				2		
	356			11.2			3								
Larned,	357	Steel	2000	10.6	80	78	2	3	1						
Pawnee	358			11.3			15			2	1				10/15/42
Co.	359			11.0			10		2						
	445			11.2			4			184					

Legend:

F - Flat grain beetle
RW - Rice weevil
S - Sawtooth beetle
L - Lesser grain borer
FG - Foreign grain beetle
GW - Granary weevil
RF - Red flour beetle
Cd - Cadelle

Experimental Fumigation of Wheat, Corn, and Grain Sorghum

Experimental fumigations were continued during the quarter, concluding the work which has been in progress since June. The results in wheat and sorghum are given in table 10. In wood bins it appears that a dosage of six gallons of Dowfume 75 per 1000 bushels is sufficient to give good results, and that more than two gallons per 1000 bushels of Dowfume Br-10 will be required to give dependable results.

Experimental fumigations of corn in Iowa were continued during the quarter. Several mixtures were used which contained substitute materials, with the object of getting advance information on the materials, in case those now in use became scarce or unobtainable due to war necessity. The results are presented in table 11.

From the results obtained in the experimental fumigation work during the past season, it is evident that the effectiveness of the various fumigants varies with different bins. The factors of temperature, amount of dockage, wind velocity, all exert a strong influence on results, and it is probably true that within practical limits, completely satisfactory kills under all conditions cannot be guaranteed. The dosages established as a result of experimental work will undoubtedly give good kills under most conditions, and the experienced fumigator will recognize unusual circumstances which require increased dosages.

Table 10: Summary of results obtained in experimental fumigation, Hutchinson, Kansas, October and November, 1942. (Analysis of fumigant mixtures is given in list at end of table.)

Bin Number	Capacity (bu.)	Dosage per 1000 bu. (gals.)	Amount used (gals.)	Kill (%)	Remarks
Wood Bins		Dowfume 75			
13-5	1500	6	9	98	Wheat
13-6	"	6	9	99.5	"
13-10	"	6	9	100	"
13-11	"	6	9	98	"
		Dowfume Br-10			
13-7	1500	2	3	67	Wheat
13-8	"	2	3	99.5	"
Steel Bins		Dowfume 75			
½-3	1000	8	8	99	Sorghum
2-12	"	4	4	80	Wheat
3-12	"	4	4	99.7	"
1-2	"	5	5	100	"
1-3	"	5	5	99	"
1-4	"	6	6	100	"
1-5	"	6	6	100	" (1 live insect)
309	2000	5	10	100	"
310	"	5	10	100	"
311	"	5	10	100	"
9-10	2740	4	11	100	"
10-1	"	4	11	94	"
10-2	"	4	11	100	"
5-4	"	4	11	100	"
6-1	"	4	11	88	" (Much frass)
6-4	"	4	11	97	"
9-7	"	4	11	100	"
11-3	"	4	11	38	" (5% dockage)
11-4	"	4	11	86	" (Fumigant put
11-5	"	4	11	91	" (on S. side
					(of bins)
		Dowfume 75-P			
3-9	1000	4	4	99.5	Wheat
4-6	"	5	5	100	"
2-5	"	6	6	100	"
8-9	2740	4	11	93	"
10-9	"	4	11	86	"
10-10	"	4	11	70	"
7-1	"	5	13.5	95	"
9-11	"	5	13.5	100	"
11-9	"	5	13.5	100	"

Table 10 (continued)

Bin Number	Capacity (bu.)	Dosage per 1000 bu. (gals.)	Amount used (gals.)	Kill (%)	Remarks
		Dowfume Br-10			
312	2000	2	4	99	Wheat
313	"	2	4	96	"
314	"	2	4	98	"
9-10	2740	1.5	4	62	"
9-12	"	1.5	4	80	"
10-11	"	1.5	4	65	"
		F-1			
4-9	1000	2	2	100	Wheat (1:4.3 mix/CCl_4)
8-12	"	2	2	98	" (1:7 mix/CCl_4)
10-12	"	2	2	98.5	" (" " ")
9-13	"	2	2	99.5	" (" " ")
1-1	"	2	2	100	" (" " ")
7-10	2740	2	5	89	" (" " ") (Poor application)
		F-28			
4-11	1000	2	2	100	Wheat (F_{28}-mix CCl_4 1 - 9)
		F-1 and F-28 Mixture			
4-8	1000	2	2	100	Wheat (F_1-F_{28}-mix CCl_4 1-1-18)
4-10	"	2	2	100	" (")
		Allyl Bromide			
4-7	1000	2	2	100	Wheat (972 grams in 2 gals. CCl_4)

Analyses of Fumigant Mixtures

Dowfume 75: Carbon tetrachloride 25%; Ethylene dichloride 75%.
Dowfume Br-10: Carbon tetrachloride 22½%; Ethylene dichloride 67½%; Methyl Bromide 10%.
Dowfume 75-P: Carbon tetrachloride 25%; Propylene dichloride 75%.
F-1: Acrylonitrile in carbon tetrachloride.
F-28: Trichloroacetonitrile in carbon tetrachloride.

Table 11: Summary of results obtained in experimental fumigation of corn in Iowa, November, 1942.

Bin Kind Location-No.	Capacity (bu.)	Dosage per 1000 bu. (gals.)	Amount used (gals.)	Kill (%)	Remarks
Steel bins	Carbon tetrachloride 72%; carbon bisulphide 20%; methyl bromide 8%				
Ogden 260	2000	2	4	94.4	
" 287	"	2	4	100	
" 464	2740	2	5	100	
Kelley 185	"	2	5.5	98.1	
	Carbon tetrachloride 74%; carbon bisulphide 20%; methyl bromide 6%				
McCallsburg 200	2000	2	4	90.9	
" 201	"	2	4	93.4	
Zearing 768	2740	2	5.5	93.9	
" 769	"	2	5.5	89.2	
	Methylene chloride 90%; carbon bisulphide 10%				
Ellsworth 577	2000	2	4	50.6	
" 576	"	2	4	36.0	
Zearing 770	2740	2	5.5	53.8	
" 771	"	2	5.5	34.9	
	Methylene chloride 90%; isopropyl formate 10%				
Roland 702	2740	2	5.5	30.7	
" 703	"	2	5	43.9	
	Carbon tetrachloride 87.5%; B-methylallyl chloride 12.5%				
McCallsburg 202	2000	2	4	86.7	Poor kill in top 3"
	Carbon tetrachloride 81.2%; acrylonitrile 18.8%				
Boone 299	2740	2	5	93.8	1:4.3 mix
Ogden 452	"	2	5	95.0	" "
	Carbon tetrachloride 81.2%; acrylonitrile 15.6%; trichloroacetonitrile 3.1%				
Boone 409	2740	2	5	100	
	Carbon tetrachloride 90%; acrylonitrile 5%; trichloroacetonitrile 5%				
Boone 308	2740	2	5	100	
	Carbon tetrachloride 90%; trichloroacetonitrile 10%				
Boone 414	2740	2	5	99.7	

Table 11 (continued)

Bin Kind Location	-No.	Capacity (bu.)	Dosage per 1000 bu. (gals.)	Amount used (gals.)	Kill (%)	Remarks
		Carbon tetrachloride 25%; ethylene dichloride 75%				
Olds	95	2000	4	8	97.2	
"	114	"	4	8	78.3	
"	91	"	4	7.5	93.1	
"	119	"	4	7	86.2	
New London	159	2740	4	11	98.9	
" "	162	"	4	11	95.8	
" "	166	"	4	10.5	98.8	
" "	193	"	4	10	99.6	

Results with Different Methods of Applying Fumigant

In the course of the experimental fumigations, the fumigant was applied by several different methods:

1. Full dosage applied on center surface under Kraft paper cover.

2. Half dosage applied on center surface under Kraft paper cover.

3. One-fifth of dosage applied in five places--center, north, south, east, and west quadrants.

4. Sprayed evenly over the entire surface.

The results obtained by the different methods show that the most uniform distribution of the gas throughout the grain mass is obtained when the fumigant is applied as a coarse spray evenly over the entire surface of the grain. When the fumigant is applied in the center under a Kraft paper cover, check cells placed in different parts of the bin showed that the gas fans out from the point of application in a cone-shaped pattern, very little mortality occurring in the upper portion of the grain mass.

Effect of Fumigation on Germination of Wheat and Corn Stored in Steel Bins

As noted in the previous report, studies were then in progress on the effect of fumigation on wheat and corn stored in steel bins. Preliminary work indicated that fumigant mixtures containing methyl bromide had a deleterious effect on germination. A series of bins at both Hutchinson and Jamestown, scheduled for two annual fumigations, showed abnormal reductions in germination. These bins had been fumigated with a mixture containing 10 percent methyl bromide. A duplicate series receiving no treatment, showed only the expected normal decrease. With the discovery during the season that fumigants are retained for long periods (2 to 14 weeks) in tight steel bins, it is probable that the long periods to which the grain was exposed explain why the germination was adversely affected. The results of the tests are given in table 12. It will be seen that at Jamestown, bins fumigated with a fumigant containing 10 percent methyl bromide in November, 1941, showed an average drop in germination of 7 percent by February, 1942, while in a similar series of untreated bins the decrease was only 2 percent. By August, 1942, however, these same bins had dropped on an average of 23 percent, whereas unfumigated duplicates had decreased only 6 percent.

At Hutchinson bins fumigated with the same mixture in November, 1941, showed an average decrease of 13 percent by April, 1942, while the check bins dropped only one percent in germination. The bins in the fumigation series were again fumigated in June, 1942, and by July showed an average decrease in germination of 40 percent, while those in the unfumigated series showed a drop of only 6 percent.

During September, a series of corn bins in the vicinity of Ames, Iowa, were fumigated with various mixtures, all containing 10 percent methyl bromide. The bins were sampled a month after fumigation and the germination was determined. The results are tabulated in table 13. No effect on germina tion is as yet apparent. It is planned to sample these bins periodically to determine if there is any subsequent reduction in germination.

Table 12: -- Effect of fumigation on germination of wheat stored in steel bins, Jamestown, N. Dak.

Bin No.	Const.	Date sampled (1941)	Germination (%)	First fumigation (1941)	Date sampled (1942)	Germination after first fumigation	Pot. change	Date sampled (1942)	Germination (%)	Total Pot. change	
Dowfume Br-10 - carbon tetrachloride 22.5%; ethylene dichloride 67.5%; methyl bromide 10%.											
R-1	FWR	7/23	94	11/5	2/3	92	-2	8/14	65	-29	2740-bushel bins
R-2	"	7/22	89	11/5	2/3	70	-19	8/14	56	-33	
S-1	"	7/24	92	11/5	2/3	73	-19	8/14	60	-32	
P-5	Solid L	7/29	87	11/5	2/4	83	- 4	8/3	72	-15	
Q-5	"S	7/29	91	11/5	2/4	89	-21	8/4	55	-36	
R-5	Perf. L	7/26	93	11/5	2/3	84	-9	8/14	61	-32	
S-4	"	7/26	94	11/5	2/3	85	-9	8/14	75	-19	
G-5	FWR	7/31	90	11/5	2/21	90	0	8/14	84	-6	1000-bu.bins
H-5	"	7/31	95	11/5	2/21	96	+1	8/14	90	-5	
Average			92			85	-7		69	-23	
Unfumigated Bins - No treatment series											
J-1	FWR	7/9	97		2/18	94	-3	8/10	91	-6	2740-bu.bins
K-1	"	7/11	90		2/16	90	0	8/13	85	-5	
K-2	"	7/11	91		2/16	91	0	8/13	89	-2	
P-3	Solid L	7/30	84		2/4	84	0	8/4	79	-5	
Q-3	"	7/29	90		2/4	93	+3	8/15	88	-2	
R-3	Perf. L	7/25	94		2/3	93	-1	8/17	not rec'd		
S-2	"	7/30	93		2/3	87	-6	8/17	84	-9	
G-3	FWR	7/31	95		2/20	91	-4	8/19	not rec'd		1000-bu. bins
H-3	"	7/31	93		2/21	91	-2	8/19	" "		
Average			92			90	-2		86	-6	

Table 12 (con't.) Effect of fumigation on Wheat stored in steel bins, Hutchinson, Kansas

Bin No. (2740-bu.)	Const.	Date sampled (1941)	Germination (%)	First fumigation (1941)	Date sampled (1942)	Germination after first fumigation	Pct. change	Second fumigation (1942)	Date sampled (1942)	Germination (%)	Total Pct. change
Dowfume Br-10											
9-1	FW	June	78	11/20	April	74	-4	June	July	40	-38
10-1	"	"	76	"	"	44	-32	"	"	9	-67
10-2	"	"	85	"	"	80	-5	"	"	39	-46
9-2	Solid L	"	80	"	"	79	-1	"	"	45	-35
10-3	"	"	78	"	"	63	-15	"	"	39	-39
9-3	Perf. L	"	71	"	"	71	0	"	"	61	-10
11-1	"	"	89	"	"	61	-28	"	"	48	-41
Average			80			67	-13			40	-40
Initial fumigation, July, 1941, with carbon bisulphide; no subsequent treatment											
5-1	FW	June	86		April	84	-2		July	80	-6
5-7	"	"	83		"	78	-5		"	75	-8
5-8	"	"	87		"	73	-14		"	83	-4
5-9	"	"	81		"	82	+1		"	77	-4
6-2	"	"	81		"	89	+8		"	80	-1
7-11	"	"	81		"	83	+2		"	76	-5
7-12	"	"	81		"	83	+2		"	73	-8
9-4	"	"	86		"	85	-1		"	77	-9
9-5	"	"	81		"	77	-4		"	74	-7
11-8	"	"	81		"	84	+3		"	73	-8
Average			83			82	-1			77	-6

Table 13: -- Effect of fumigation on germination of corn stored in steel bins, Ames, Iowa

Bin No.		Germination* before fumigation (%) Top half	Germination* before fumigation (%) Bottom half	Germination after fumigation (%) Top half	Germination after fumigation (%) Bottom half	Change (%) Top half	Change (%) Bottom half
2000-bu. bins							
Ogden	259	83	94	88	77	+5	-17
"	260	64	95	65	89	+1	-6
"	287	79	91	84	89	+5	-2
"	113	94	95	94	93	0	-2
McCallsburg	200	61	--	52	70	-9	--
"	201	86	58	83	50	-3	-8
Ellsworth	275	79	93	34	96	-45	+3
"	576	82	94	87	92	+5	-2
"	577	84	95	90	92	+6	-3
Kelley	175	84	82	94	87	+10	+5
"	172	89	92	90	98	+1	-6
Average		80	89	78	85	-2	-4
2740-bu. bins							
Ogden	464	79	83	80	86	+1	+3
Kelley	185	58	--	51	91	-7	--
Zearing	768	83	89	84	90	+1	+1
"	769	63	91	69	82	+6	-9
"	770	55	--	8	91	-47	--
"	771	62	89	74	91	+12	+2
Roland	702	51	--	16	89	-35	--
"	703	53	--	76	94	+23	--
Average		63	88	57	88	-6	0

* Germinations were run by J. C. Frankenfeld of the Bureau's Manhattan, Kansas, station.

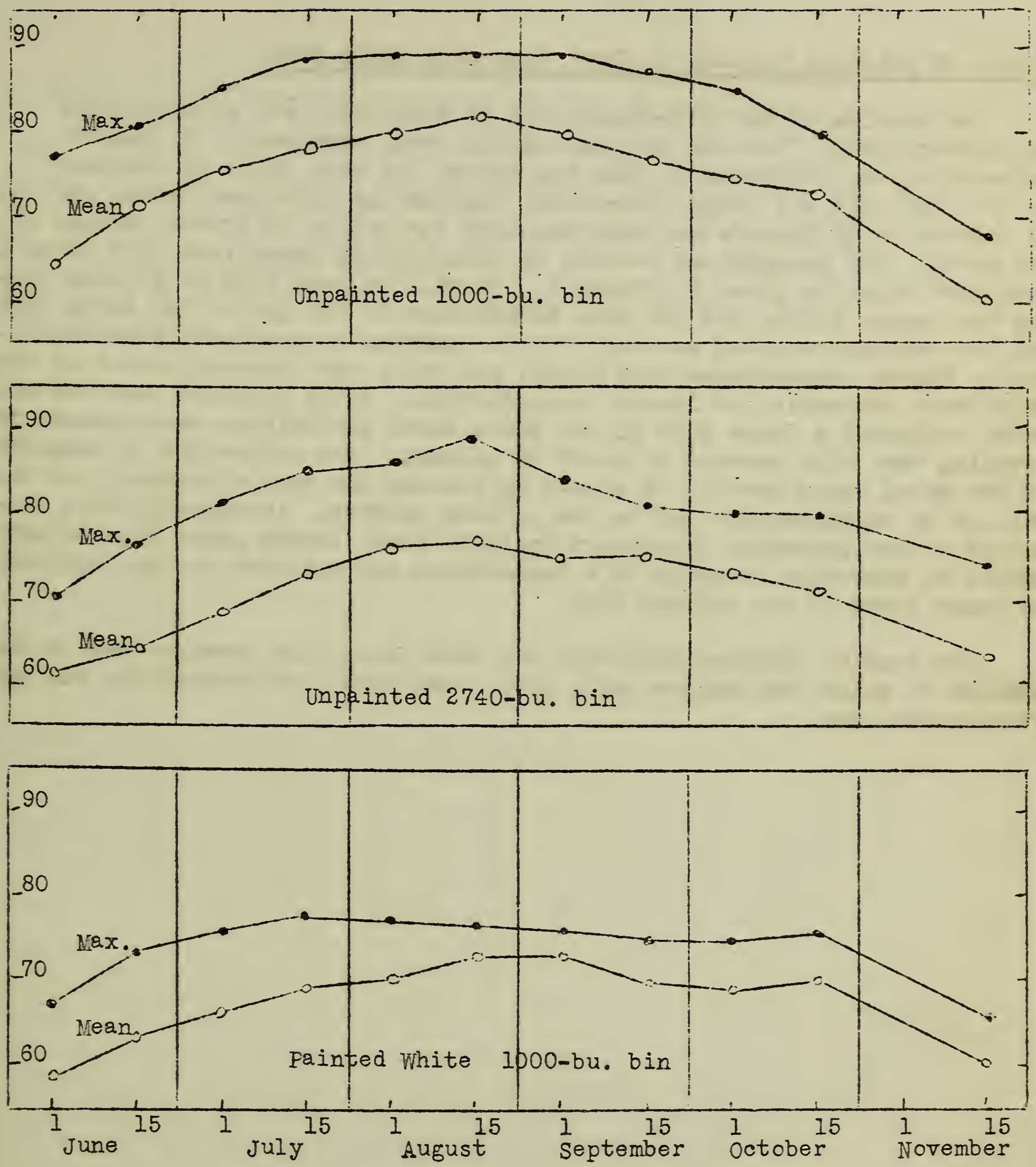

Figure 4: -- Comparison of maximum and mean temperatures of wheat stored in painted and unpainted steel bins, Hutchinson, Kansas, June to November, 1942.

Effect of Painting Outside of Steel Bins with White Paint

The outside of one 1000-bushel bin at Hutchinson was painted white in October, 1941. The bin has received no other treatment. No insect infestation has developed in this bin during the past year, in contrast to the fact that all other 1000-bushel bins on the site have become seriously infested with insects and have required fumigation to prevent damage to the grain. The temperature records on this bin, in comparison with those on unpainted bins, is given in figure 4. It will be seen that at no time during the summer months did the mean temperature of the grain rise above 73°F. and the maximum recorded was only 78° F., whereas in unpainted bins considerably higher temperatures were noted, and for a considerable period of time, which were favorable for insect reproduction. It is apparent that the white paint reflected a large part of the sun's heat, preliminary measurements indicating that this amounts to about 90 percent. The difference in temperature of the metal could readily be sensed by placing the hand alternately on the wall of an unpainted bin and on the painted surface. Laboratory tests conducted at the Manhattan laboratory indicate that stored grain insects are unable to reproduce in grain of a temperature and moisture content similar to those found in the painted bin.

The results obtained with this bin have shown such promise that it was decided to paint the outside walls of an additional 1000-bushel bin and two 2740-bushel bins.

Results with Repellent and Protective Covers on the Surface of the Grain.

In an attempt to prevent or reduce infestation, repellent and protective covers were placed on the surface of the grain in three bins in the fall of 1941. These covers consisted of (1) Kraft paper treated with nicotine sulphate, (2) cotton bat, and (3) cotton bat sprayed with oil. During the present quarter, these bins began heating because of insect infestation and were all infested to about the same degree. It was necessary to remove the covers and fumigate in order to prevent serious damage to the grain. No further experiments with this type of cover are planned, since the cost is high and efficiency low.

Interior Wall Treatment for Wooden Bins

With the erection of large numbers of wooden bins in the winter wheat region for storage of surplus wheat, it became necessary to obtain information on the effectiveness of repellent substances for the protection of these bins from the wood-boring species of stored grain insects such as the cadelle and the lesser grain borer. Earlier in the year tests were conducted at Manhattan, Kansas, to determine the efficiency of repellents in preventing damage by the wood-boring species. As a result of these tests, several materials showed considerable promise, and it was decided to treat the interior walls of a series of wooden bins at Hutchinson with some of the most efficient of the materials tested. Altogether, eight bins have been so treated and have been filled with wheat during October and November. The various treatments are given in table 14.

Table 14: -- Inside Wall Treatments for Wooden Bins (1500-bushel), Hutchinson, Kansas, 1942.

Bin No.	Treatment	Parts of bin treated	Application	Amount used	Cost of material	Total cost for entire bin including labor***
13-1	K1127	1 coat, E & W walls and floor; 2 coats on S wall	Sprayed	4 gals.		
13-2	White paint	Floor, walls, 1 coat; 2 coats on S wall	Brushed	4 gals.	$12.00	$17.00
13-7	40% nicotine sulphate	1 coat on S wall	Brushed	5 lbs.	7.00	37.50
13-8	White lead	1 coat, E, W, N walls and floor; 2 coats on S wall	Brushed	50 lbs.	10.00	15.00
13-9	Dowicide 3	1 coat on W wall	Brushed	1 gal.		
	Dowspray 208	1 coat on S wall	Brushed	1 gal.		
13-10	Dowspray 208*	1 coat on floor & walls	Sprayed	4 gals.		
13-11	Whitewash**	1 coat				
13-11	Whitewash**	1 coat, E, W, N walls; 2 coats on S wall	Brushed	10 gals.	.80	2.80

* By mistake one coat of K1127 was applied to south wall before 208 was put on.
** Recipe for whitewash: 10# hydrated lime; 5# white cement; 2# coarse salt; 5 gals. water.
*** Labor cost figured at $.50 per hour.

Dowspray 208 is a solution of phenothioxine in deobase oil.
Dow K1127 is a solution of tetrachlorphenoxyethoxy ethyl chloride in deobase oil.

Effectiveness of Turning and Cleaning Wheat Stored in Steel Bins as A Means of Reducing Insect Infestation.

Up to the present time only one bin at the Hutchinson storage site has been turned and cleaned. During the winter of 1941-42, a quantity of grain in bin 7-1 became crusted on the surface because of insect infestation and resultant heating. Fumigation failed to bring the infestation under control, and as it was desired to get information on the effect of turning and cleaning on insect populations, this bin was emptied early in May, 1942. The grain was run out of the bin into a truck and thence was run over an 8-foot screen into another bin, No. 12-4. A comparison of samples taken before and after cleaning indicated that about 90 percent of the free living insects had been removed along with most of the dockage. The grain was then fumigated with carbon bisulphide and was given an oil surface treatment.

During the turning and cleaning process an attempt was made to collect all of the insects and dockage removed by the screen. Later in the season, however, it became evident that at least five near-by bins had become infested by insects which had escaped during the cleaning process, and it was necessary to fumigate two of them in August to stop heating. The insects causing trouble, the lesser grain borer and the rice weevil, were the two species most aabundant in the grain that was turned and cleaned. Further, no other 2740-bushel bins had become infested up to that time, and traps operated on the bin site had not shown any large movements of these species. The November quarterly sampling showed that three bins within 100 feet of 12-4 contained over 90 percent of the rice weevil population on the entire bin site.

Similar migrations from screenings were observed at other bin sites, where cleaning operations were in progress during October. At one site screenings were placed in an empty bin and large numbers of rice weevils were seen migrating from the bin. Samples were taken from near-by bins before turning and again two weeks after turning. The results are given in table 15.

Table 15: -- Comparison of Insect Infestation in Bins Before and Two Weeks After Turning and Cleaning Adjacent to Bin in Which Screenings Were Stored.

Bin No.	Number of insects per 1000-gram sample											
	Before turning						Two weeks after turning					
	Rice weevil	Lesser grain borer	Flat grain beetle	Rust-red flour beetle	Sawtooth grain beetle	Total	Rice weevil	Lesser grain borer	Flat grain beetle	Rust-red flour beetle	Sawtooth grain beetle	Total
308	1	1	0	0	0	2	7	1	0	0	1	9
309	4	0	1	0	0	5	9	4	0	0	0	13
310	4	7	0	3	2	16	81	52	1	0	0	134
311	8	10	2	0	0	20	121	0	20	1	0	142
312	0	0	34	0	0	34	0	0	3	0	0	3
313	0	0	9	0	0	9	0	0	35	0	0	35

It may be seen that there was an increase in population in all of the bins except one.

As a result of the above observations on turning and cleaning, several problems arise:

1. A simple screen will not clean wheat adequately. The cleaning is accomplished either when the grain falls on a screen or while it is rolling very slowly over the screen.

2. Many of the insects found in stored wheat closely approximate the size of a wheat kernel. Hence, screen of a mesh small enough to retain wheat will also retain some insects. For this reason, it is doubtful if a gravity screen can be developed that will be fully effective in removing free living insects. Further, the larvae of the most destructive species, such as the lesser grain borer and rice weevil, live within the grain and cannot be removed by any mechanical process.

3. Agitation of the grain during the turning process induces migration by the insects, but if the turning is done during cold weather, the hazard of migration can be reduced. However, under field conditions, much of the turning is done during the warm season of the year, and is usually more dependent upon availability of equipment and labor, rather than temperature.

Recommendations for the Control of Insects in Wheat Stored in Steel Bins

Much valuable information on the insect problems of wheat stored in steel bins has been obtained as a result of studies which have been in progress during the past 18 months at the Experimental Wheat Storage sites at Jamestown, North Dakota, and at Hutchinson, Kansas. These results have been discussed in the various quarterly reports, but it seems worthwhile to present a brief summary of them at this time.

I. Northern Spring Wheat Region. (Represented by Jamestown, N. Dak.)

1. At the Jamestown, N. Dak., storage site, no insect infestations of consequence have developed as yet, and the indications are that low winter temperatures in that region can be depended upon to keep insect populations under control. The temperature of the grain falls to low levels during the winter months, below 32° F. in most bins, with the result that during the summer, grain temperatures never rise to a point at which insects can increase rapidly.

II. Hard Winter Wheat Region. (Represented by Hutchinson, Kansas)

1. At the Hutchinson, Kansas, storage site insect infestation has been a serious threat in the safe storage of the grain,

2. Grain stored in steel bins in the southern half of the hard winter wheat region is subject to insect infestation caused by migration of the insects into the grain during the summer months, especially during July and August.

3. Dry, clean grain, of high quality, is less subject to infestation than grain of high dockage and low quality.

4. Fumigation is at present the most practical and economical method of controlling insects in grain stored in steel bins. At present prices, the cost of fumigation amounts to about $4.00 per 1000 bushels.

5. Grain stored in bins of 2740-bushel capacity will probably require one annual fumigation, usually in October, in order to prevent serious insect infestation.

6. Grain stored in 1000-bushel bins will require two annual fumigations, one in August and a second in October.

7. In most cases, insect infestations develop in the upper half of the south quadrant of the bins.

Tests with Various Treatments for Wooden Grain Bins to Prevent Burrowing of Grain-Infesting Insects.*

The model wooden bins included in this test have now been subjected to the attack of grain-infesting insects for a period of 6 months. The results of the examination of these bins at the end of this period are given in table 16. It will be noted that many of the treatments have failed to afford protection to the woodwork from the boring attack of the cadelle or the lesser grain borer. Seven treatments still afford almost perfect protection, white lead paint, Pyrefume 20 (Pyrethrum extract (20 - 1), Lethane 384 (butyl carbitol thiocyanate), nicotine sulfate 40%, Thanite (secondary terpene-alcohol thiocyanyl acetate), Termi-tox (pentachlorphenol), and white wash.

Table 16:--Condition of wooden bins after 6 months exposure to attack by the cadelle and the lesser grain borer.

No.	Treatment of bin	Number of holes bored in woodwork: After 1 Month	After 2 Months	After 4 Months	After 5 Months	After 6 Months
1	White lead paint, 2 coats	0	0	0	0	0
2	" " " , 2 "	0	0	0	0	0
3	Boiled linseed oil, 2 coats	0	0	10	30-40	40-50
4	" " " 2 "	11	12	15	25	25-30
5	Spar varnish, 2 coats	2	1	4	9	10
6	" " 2 "	2	2	6	15	20
7	Nitroethane, 2 coats	4	5	22	40-50	40-50
8	" 2 "	0	2	19	30	30-40
9	K1127, 2 coats	0	1	1	1	1
10	" 2 "	0	1	1	1	1
11	Dowspray 208, 2 coats	0	1	1	0	5
12	" " 2 "	0	0	0	0	0
13	Pyrefume 20, 2 coats	0	0	0	0	1
14	" " 2 "	0	0	0	0	0
15	Lethane 384 special, 2 coats	0	0	0	0	1
16	" " " 2 "	0	0	0	0	1
17	Nicotine sulfate 40%, 1 coat	0	0	0	0	1
18	" " " 1 "	0	0	0	2	2
19	Thanite special, 2 coats	0	0	0	0	0
20	" " 2 "	0	0	0	0	0
21	Mineral oil, 2 coats	0	0	18	25	40-50
22	" " 2 "	0	0	22	40	35-40
23	White wash, 1 coat	0	0	0	0	2
24	" " 1 "	1	1	1	1	4

* Reported by R. T. Cotton in cooperation with Mr. H. D. Young, Division of Insecticide Investigations.

Table 16 continued

No.	Treatment of bin	Number of holes bored in woodwork After 1 Month	After 2 Months	After 4 Months	After 5 Months	After 6 Months
25	White paint + 10% nitroethane, 1 coat	3	3	3	4	11
26	" " + 10% " 1 coat	0	1	3	4	7
27	" " + 10% K1127, 1 coat	0	3	6	12	18
28	" " + 10% " 1 "	1	3	4	4	19
29	" " + 10% Dowspray 208, 1 coat	0	0	5	6	15
30	" " + 10% " " 1 "	0	2	4	10	10
31	" " + 10% Pyrefume 20, 1 coat	0	0	1	6	6
32	" " + 10% " " 1 "	0	12	12	10	11
33	" " + 10% Lethane 384, 1 coat	2	3	4	14	17
34	" " + 10% " " 1 "	0	3	4	4	7
35	" " + 10% Nicotine Sulfate 40%, 1 coat	0	0	3	4	4
36	" " + 10% " " " 1 "	0	1	5	8	8
37	" " + 10% Thanite, 1 coat	6	6	6	9	9
38	" " + 10% " 1 "	0	1	2	15	20
39	" " + 10% Winter green oil, 1 coat	1	6	10	13	14
40	" " + 10% " " " 1 "	0	1	8	9	9
41	" " + 10% Anise, 1 coat	1	2	4	10	10
42	" " + 10% " 1 "	4	3	8	9	9
43	Mineral oil + 10% Lethane 384, 1 coat	7	4	18	40	40-50
44	" " + 10% " " 1 "	0	1	1	45	40-50
45	" " + 10% Pyrefume 20, 1 coat	1	3	5	20	40-50
46	" " + 10% " " 1 "	0	1	3	12	40-50
47	" " + 10% Nicotine Sulfate, 1 coat	1	0	0	5	5
48	" " + 10% " " 1 "	0	0	0	8	10
49	Melted paraffin	2	1	8	25	25
50	" "	1	2	25	45	50
51	" "	5	2	20	24	24
52	" "	2	3	12	20	30-40
53	1% in water of nicotine sulfate 40%	10	10	17	40-50	50-60
54	" " " " " " "	6	6	15	50-60	50-60
55	Check untreated	12	15	30-40	60-80	60-80
56	" "	16	20-30	30-40	80-100	80-100
57	" "	10	20-30	30-40	80-100	80-100
58	" "	10	20-30	30-40	60-80	60-80
59	" "	15	20-30	30-40	70-90	70-90
60	" "	11	20-30	30-40	50-60	50-60
61	Termi-tox concentrate, 1 coat	0	0	0	0	4
62	" " 1 "	0	0	0	0	0
63	1 pt. Termi-tox conc. 4 pts. naphtha	0	0	0	0	0
64	" " " " " "	1	1	1	1	4
67	5 Plywood		20	29	60-80	60-80
68	" "		18	37	60-80	60-80

Effect of Grain Moisture on the Survival, Reproduction, and Development of Stored Grain Insects*

These tests are the continuations of tests which have been in progress for the past two years, in which an effort is made to evaluate the factors of moisture and temperature on the survival, reproduction and development of six common species of stored grain insects. The tests herewith reported on deal with two series of 12, 13, and 14% moisture wheats at constant temperatures of 70 and 75° F.

In a previous series of tests conducted at 70° F. with 9, 10, and 11% wheat, it was found that none of the species reproduced in 9% wheat. The granary weevil reproduced, although sparingly, in 10 and 11% wheat, and the rice weevil reproduced in 11% wheat. None of the other four species, namely, the confused flour beetle, lesser grain borer, sawtoothed grain beetle, and the rust red flour beetle showed any signs of reproduction at this temperature in the above mentioned moisture variants. Reproduction under these conditions was practically insignificant considering the large number of individuals involved and the length of time they were exposed to the wheat. It therefore seemed advisable to increase the moisture content of the wheat and repeat the tests at 70° F. This series has been in progress for nine weeks and the results of biweekly examinations are recorded in table 17. A different procedure was followed in these tests than in those previously reported. At each examination the wheat in the granary and rice weevil cultures was changed. The wheat which had been exposed to infestation was carefully screened to remove all of the insects, and placed in pint jars. New sterilized wheat, adjusted to the required moisture content was put into the rearing flasks and the original adults were added. The wheat which had been exposed to infestation was kept at the same temperature at which it had been exposed during the infestation period. At the first sign of adults issuing from these lots, the wheat is screened daily. All adults are removed, counted and recorded. In previous tests, the series was discontinued as soon as the first progeny were recovered.

From the standpoint of survival, we again find that, in general, as the moisture content of wheat is increased the percentage of survival is also increased. Thus in 12% moisture wheat, held at a constant temperature of 70° F. there was a small amount of mortality recorded for practically all species, except the rice weevil, which showed a survival of only 51%. In the 13 and 14% wheat the percentage of survival was higher for most of the species than was true of the 12% wheat. In the case of the rice weevil there was no difference in the 13% wheat, but was somewhat higher in the 14% wheat. The sawtoothed grain beetle also showed a higher percentage of survival in 14% than in 13% wheat.

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* Reported by R. T. Cotton and J. C. Frankenfeld.

Reproduction of granary and rice weevil occurred in all three moisture variants at 70° F. The table below gives the first date on which adults were recovered from wheat which was exposed to infestation from October 20 to October 27, 1942.

Species	Date of first emergence of adults					
	at 70° F.			at 75° F.		
	In 12% wheat	In 13% wheat	In 14% wheat	In 12% wheat	In 13% wheat	In 14% wheat
Granary weevil	12/14/42	12/11/42	12/9/42	12/7/42	12/6/42	12/ 1/42
Rice weevil	12/14/42	12/ 9/42	12/7/42	12/6/42	12/1/42	11/28/42

Assuming that eggs were laid at approximately the same date in each culture, it will be noted from the above table that there is a tendency for the reduction in the time of development from egg to adult as the moisture content of the wheat is increased. That the moisture content of wheat also affects the rate of reproduction is indicated by the increase in adults recovered in the 13 and 14% wheat as compared with the 12% wheat. The number of progeny recovered at the end of the nine weeks is recorded in table 17.

In the series of tests conducted at a constant temperature of 75°F., all species of insects showed a higher percentage of survival in the higher moisture wheat. Comparing the moisture variants in the 70° F. series with the corresponding ones in the 75° F. series, shows that invariably a higher percentage of survival was obtained with each species at the lower temperature. This same relationship was observed in a series of tests with 9, 10, and 11% moisture wheat at 70 and 75° F.

From the standpoint of reproduction we find that all species except the confused flour beetle and the lesser grain borer reproduced in 12% wheat; all species except the lesser grain borer and rust red flour beetle reproduced in 13% wheat; and all species except the lesser grain borer reproduced in 14% wheat. Reproduction of the four species in 12% wheat was first observed after the 7th week. Larvae of the confused flour beetle were first observed in 13% wheat after 5 weeks, while with the other species reproduction was not observed until the 7th week. Reproduction by the confused flour beetle, sawtoothed grain beetle, and rust red flour beetle in 14% wheat was observed at the end of five weeks, while first adult progeny of the granary weevil and rice weevil were obtained by the end of the 7th week. It should be remembered that in the case of the latter species, evidence of reproduction is not discernible until after the adult progeny issue from the wheat berry. Evidence of reproduction by the bran bugs is discernible in the early larval stages as they feed externally on the grain.

Development of the immature stages of the granary and rice weevil is more rapid at 75° F. than at 70° F. (See table 18), and, as was true in the 70° F. series, the period of time required for the completion of development from egg to adult decreased as the moisture content of the grain increased. Furthermore, there is a much higher rate of reproduction in all moisture variant wheat at 75° F. than at 70° F.

At the end of nine weeks, 1 adult sawtoothed grain beetle progeny was recovered in each the 12 and 13% moisture wheat, and 54 in the 14% wheat. In the 70° F. series, no progeny had completed development for the same period.

Table 17:--Survival of various species of stored grain insects reared in 12, 13, and 14% moisture wheat at 70° F.#

Species of Insect	Percentage of survival after 1 Week	3 Weeks	5 Weeks	7 Weeks	9 Weeks	Number of adult progeny at end of 9 weeks
12% Wheat						
Granary weevil	100	100	97	97	95*	44
Rice weevil	100	100	100	52	51*	164
Confused flour beetle	100	100	100	98	65	
Lesser grain borer	95	87	85	83	80	
Sawtoothed grain beetle	93	87	87	87	86	
Rust red flour beetle	100	99	98	91	88	
13% Wheat						
Granary weevil	99	99	99	99	99*	190
Rice weevil	100	100	100	54	50*	745
Confused flour beetle	100	100	98	98	98	
Lesser grain borer	98	97	96	94	92	
Sawtoothed grain beetle	99	93	91	91	89*	
Rust red flour beetle	100	100	99	99	99	
14% Wheat						
Granary weevil	100	100	100	100	100*	204
Rice weevil	100	100	100	69	66*	665
Confused flour beetle	100	100	100	100	99	
Lesser grain borer	100	99	97	94	91	
Sawtoothed grain beetle	100	98	98	98	96*	
Rust red flour beetle	100	100	100	100	97	

* Progeny recovered.

\# At start of experiment each culture consisted of 100 individual insects.

Table 18:--Survival of various species of stored grain insects reared in 12, 13, and 14% moisture wheat at 75° F.#

Species of Insect	Percentage of survival after 1 Week	3 Weeks	5 Weeks	7 Weeks	9 Weeks	Number of adult progeny at end of 9 weeks
12% Wheat						
Granary weevil	100	100	100	96*	93	320
Rice weevil	100	100	100	80*	76	1061
Confused flour beetle	100	100	100	87	24	
Lesser grain borer	94	91	86	83	76	
Sawtoothed grain beetle	95	91	91	85*	78	1
Rust red flour beetle	99	99	94	79*	67	
13% Wheat						
Granary weevil	100	100	100	97*	97	850
Rice weevil	100	100	100	97*	94	2705
Confused flour beetle	100	100	100*	100	100	
Lesser grain borer	97	91	84	80	74	
Sawtoothed grain beetle	97	95	95	84*	71	1
Rust red flour beetle	99	97	97	96	92	
14% Wheat						
Granary weevil	100	100	100	100*	99	582
Rice weevil	100	100	97	97*	97	2947
Confused flour beetle	100	100	100*	100	95	
Lesser grain borer	100	95	93	85	75	
Sawtoothed grain beetle	98	96	96*	92	88	54
Rust red flour beetle	100	97	97*	96	95	

* Progeny recovered.

\# At start of experiment each culture consisted of 100 individual insects.

Effect of the Amount of Dockage on the Ability of *T. confusum* to Survive and Reproduce in Wheat of Various Moisture Content.*

In previous tests conducted to determine the effect of the moisture content of wheat on the development of stored grain insects, it was observed that at temperatures below 90° F. the confused flour beetle encountered difficulty in reproducing in whole wheat. But, after a sufficient period of time had elapsed for the adults to have milled a considerable quantity of flour, reproduction eventually occurred. In other tests it was observed that this insect reproduces readily in flour with a moisture content as low as 8% at temperatures of 70° F. or above. Unquestionably, therefore, it becomes obvious that the female beetle oviposits, but that the young larva on hatching does not find sufficient food to develop in clean whole grain.

To verify these assumptions, a series of tests were set up in which varying amounts of ground whole wheat was added to the cultures of clean wheat. In these tests wheats with 8, 12, and 14% moisture were used. The wheat was carefully cleaned by screening through a 10 mesh sieve, and passing the grain through a strong current of air. In this way only the berries larger than those that would readily pass through the sieve were used. All dust and chaff was blown out. For each of the moisture variant wheats, the following wheat and dockage combinations were used:

1. Clean whole wheat berries
2. Clean whole wheat plus 0.5% dockage
3. " " " " 1.0% "
4. " " " " 2.0% "
5. " " " " 4.0% "
6. " " " " 8.0% "

These tests have been in progress for four weeks, and the results of weekly examinations are summarized in table 19. In the 8% moisture wheat the percentage of survival dropped to 72% at the end of four weeks. In the other cultures in this series there were only slight insignificant differences in survival. In none of the cultures were there any signs of reproduction. In wheat with a moisture content of 12%, there was no difference in the percentage of survival for the different cultures, but a very noticeable difference in reproduction. In all of the cultures to which dockage had been added, reproduction was observed after two weeks. One pupa was found in each of two cultures at the end of three weeks. At the end of four weeks a few very small larvae were found in the culture of clean wheat, and numerous larvae of various stages of development were found in each of the other cultures, while 6 pupae were found in the culture containing 8% dockage.

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* Reported by R. T. Cotton and J. C. Frankenfeld.

Table 19: -- Survival of *T. confusum* reared in 8, 12, and 14% moisture wheat with varying percentages of dockage at 80° F.

Rearing media	Percentage of survival after 1 Week	2 Weeks	3 Weeks	4 Weeks
8% Moisture				
Clean whole wheat berries	100	97	87	72
Same plus 0.5% dockage	100	100	100	99
" " 1.0% "	100	100	98	90
" " 2.0% "	100	99	96	89
" " 4.0% "	100	100	99	98
" " 8.0% "	100	100	100	100
12% Moisture				
Clean whole wheat berries	100	99	99	99[a]
Same plus 0.5% dockage	100	100[a]	100	100
" " 1.0% "	100	100[a]	100	100
" " 2.0% "	100	100[a]	100[b]	100
" " 4.0% "	100	100[a]	100	100
" " 8.0% "	100	100[a]	100[b]	100[c]
14% Moisture				
Clean whole wheat berries	100	99	99	99[a]
Same plus 0.5% dockage	100	100[a]	100[d]	100[e]
" " 1.0% "	100	100[a]	100[d]	100
" " 2.0% "	100	100[a]	100	100[b]
" " 4.0% "	100	100	100	100
" " 8.0% "	100	99	99[a]	99

a = Progeny recovered
b = 1 Pupa recovered
c = 6 Pupae recovered
d = 2 Pupae recovered
e = 5 Pupae recovered

The same conditions were found in the cultures of 14% wheat, with slight variations. It will be noted that no reproduction has been observed in the 4% dockage culture, and that not until after the 3rd week were any larvae observed in the 8% dockage culture. Furthermore, development seemed to be more rapid in the cultures containing 0.5 and 1% dockage than in the cultures with a higher percentage of dockage. These discrepancies are undoubtedly due to experimental error in making observations. Due to the large amount of dockage it is difficult to readily detect the young larvae.

The significant fact derived from these tests to date is the importance of dockage in wheat so far as the reproduction of the confused flour beetle is concerned. Although reproduction occurred in the clean wheat after four weeks, the amount was small in comparison with the cultures containing even the lowest percentage of dockage, indicating that the larvae cannot subsist on whole clean wheat and that only after the adults have "milled" sufficient flour are a few larvae able to develop.

The fact that no reproduction has been observed in the series of 8% moisture wheat at this date is in complete agreement with tests conducted with flour.
Apparently reproduction is either delayed or development is greatly retarded, so that usually a longer period of time must elapse before larvae are found.